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Bang, Ole; Yuan, Scott Wu; Town, G.E.; Frosz, Michael Henoch; Simonsen, R.

Published in:
Proceedings EUROPT(R)ODE X

Publication date:
2010

Document Version
Publisher's PDF, also known as Version of record

IL2

PHOTONIC CRYSTAL FIBERS FOR LABEL-FREE BIOSENSING

O. Bang [a,*], W. Yuan [a], G.E. Town [b], M.H. Frosz [a], R. Simonsen [a]

[a] *DTU Fotonik, Dept. of Photonics Engineering, Technical University of Denmark, Denmark*
[b] *MQ Photonics, Dept. of Physics and Engineering, Macquarie University, Australia*

corresponding.author.oban@fotonik.dtu.dk

Photonic crystal fibers (PCFs) are well-suited for label-free biosensing. The biochemical reactions may be performed inside the holes of the fiber, making the sensor more robust, and the overlap between light and biosample can be made very large by either using so-called bandgap guidance or by optimizing the hole structure. Here we present our work on three different configurations for using PCFs for label-free biosensing:
1) Tracking the resonance of a Long-Period Grating (LPG) and how it shifts when a specific target biomolecule is captured. Our experimental work has showed that the capture of double-stranded DNA can give a shift in the resonance wavelength of 2nm, as seen in Fig. 1(b). This gives a sensitivity of 1.4 nm per nm biolayer (1.4nm/nm) [1].
2) Using a built-in two-core coupler: The two-core coupler may in the simplest configuration be operated by using a single wavelength source and tracking the intensity in the output arm [2,3]. In a more conventional way a broadband source is used to track the wavelength of maximum intensity in the output arm [2,3]. The concept is illustrated in Fig. 1(a) using an all-solid photonic bandgap two-core coupler, in which only the central hole between the two cores is infiltrated with the analyte [2]. A shift of the refractive index of the analyte from 1.4 to 1.401 gives a significant shift of the peaks [2].

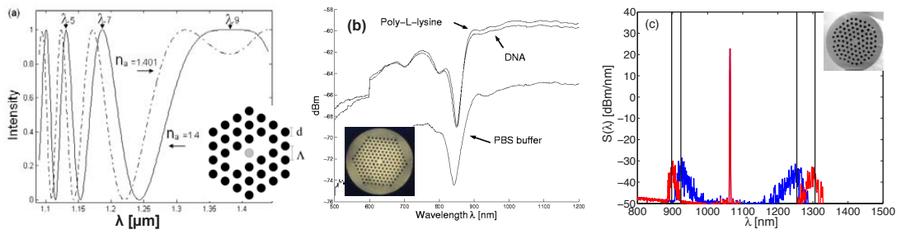

Figure 1. (a) Two-core coupler sensor: Numerically calculated intensity in output core after one coupling length, normalized to incident intensity into the input core, for two different refractive indices of the fluid in the central hole (n_a= 1.4 and 1.401). Insert shows the hole structure of the two-core bandgap PCF with black and white being two different solid materials and the shaded central hole containing the analyte. (b) LPG biosensor: Measured output spectrum, first with PBS buffer in the holes, then with Poly-L-lysine immobilized onto the inside of the holes, and finally after immobilizing double-stranded DNA onto the Poly-L-lysine layer. The shift in the grating resonance caused by DNA is 2nm, giving a measured shift of 1.4nm/nm biolayer. Insert shows the used PCF. (c) Four-wave mixing based nonlinear biosensor: An antigen capture layer is immobilized onto the inside of the holes for the capture of a specific antibody. Numerically calculated output spectrum showing how the Stokes and anti-Stokes lines shift when an antibody layer is captured. The predicted sensitivity is 10.4 nm/nm biolayer. Insert shows the used PCF.

3) Tracking the Stokes and anti-Stokes wavelengths in a nonlinear four-wave-mixing (FWM) process. Using the inherent nonlinearity of the fiber one can, using FWM, generate Stokes and anti-Stokes lines at wavelengths that are strongly dependent on the presence of a layer of biomolecules immobilized onto the inside of the holes. In Fig. 1(c) we show the results of numerical simulation of the spectrum after 50cm of fiber. The inner-most spectrum (blue) shows the output spectrum when a 40nm antigen biolayer is immobilized onto the inside of the holes. The outer-most (red) spectrum shows the output after a 5nm layer of antibody biomolecules has been captured. A sensitivity of 10.nm/nm is predicted, but there is an issue of the fiber having to have a sufficiently strong nonlinearity [4].

[1] L. Rindorf, J.B. Jensen, M. Dufva, P.E. Hoiby, L.H. Pedersen, O. Bang, Photonic crystal fiber long-period gratings for biochemical sensing, Optics Express, (2006), Volume 14, pp. 8224-8231.
[2] W. Yuan, G.E. Town, O. Bang, Refractive index sensor based on twin-core all-solid photonic bandgap fibers, IEEE Sensors Journal (2010) to appear.
[3] G.E. Town, W. Yuan, R. McCoster, O. Bang, Microstructured optical fiber refractive index sensor, Optics Letters (2010) to appear.
[4] J.R. Ott, M. Heuck, C. Agger, P.D. Rasmussen, O. Bang, Label-free and selective nonlinear fiber-optical biosensing, Optics Express, (2008), Volume 16, pp. 20834-20847.